March 28, 2017

CONFIDENTIAL MATERIALS ATTACHED
BY ELECTRONIC FILING AND HAND DELIVERY

Marlene H. Dortch
Secretary
Federal Communications Commission
445 12th Street, SW
Washington, DC 20554

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Re: ***Request for Confidential Treatment***

Proposal of Nokia to Operate as Spectrum Access Server Administrator and Environmental Sensing Capability Operator, GN Docket No. 15-319

Dear Ms. Dortch:

Pursuant to Section 0.459 of the Federal Communications Commission's ("Commission") Rules, 47 C.F.R. § 0.459, Nokia respectfully requests that certain information provided in the enclosed proposal be withheld from public inspection and afforded confidential treatment in accordance with Section 552(b)(4) of the Freedom of Information Act, 5 U.S.C. § 552(b)(4), and Sections 0.457(d)(2) and 0.459(b) of the Commission's Rules, 47 C.F.R. §§ 0.457(d)(2), 0.459(b).[1] Accordingly, the enclosed submission is labeled "Confidential – Not for Public Inspection." Nokia also is providing a redacted copy of the submission marked "Redacted – For Public Inspection."

Section 552(b)(4) of the Freedom of Information Act permits an agency to withhold from public disclosure any information that qualifies as "trade secrets and commercial or financial information obtained from a person and privileged or confidential." 5 U.S.C. § 552(b)(4). Section 0.457(d)(2) of the Commission's Rules allows persons submitting materials that they wish withheld from public

[1] Nokia does not object to the Commission sharing the filing marked "Confidential – Not for Public Disclosure" with other federal agencies pursuant to Section 0.442 of the Commission's rules, 47 C.F.R. § 0.442, and voluntarily waives its right under that rule to submit an opposition to such disclosure within ten calendar days of a request for access from a government agency. Disclosure of records to other federal government agencies is governed by the Paperwork Reduction Act, 44 U.S.C. 3510, rather than the Freedom of Information Act. Under section 3510(b), if information obtained by an agency is released by that agency to another agency, all the provisions of law that relate to unlawful disclosure apply to the agency to which information is released to the same extent and in the same manner as the provisions apply to the agency which originally obtained the information. Nokia does not object to the Commission sharing the confidential version of its filing with other government agencies so long as any receiving agency withholds the confidential information from public disclosure.

inspection in accordance with Section 552(b)(4) to file a request for non-disclosure. 47 C.F.R. § 0.457(d)(2). The requirements governing such requests are set forth in Section 0.459(b) of the Commission's rules. In accordance with Section 0.459(b) of the Commission's Rules, this request is supported by the following showing:

(1) Identification of Specific Information for Which Confidential Treatment is Sought (Section 0.459(b)(1)).

Nokia seeks to maintain confidentiality of the information marked "Confidential – Not for Public Inspection" and redacted from the version marked "Redacted – For Public Inspection." Specifically, Nokia seeks confidential treatment for information provided in sections 2.2.3, 2.2.13, 2.2.14, 3, 4.2, 4.6, and 4.7.2 of the attached proposal.

(2) Description of Circumstances Giving Rise to Submission (Section 0.459(b)(2)).

The confidential information is being filed voluntarily as part of a proposal to serve as a CBRS SAS Administrator and ESC operator in response to the Commission's Public Notice in the above-referenced proceeding.

(3) Explanation of the Degree to Which the Information is Commercial or Financial, or Contains a Trade Secret or is Privileged (Section 0.459(b)(3)).

The confidential information includes proprietary and highly sensitive commercial information detailing technical information for new services being developed, product development strategies, future business plans and pricing methodologies. Such information is plainly sensitive commercial information that companies would normally keep confidential and that Nokia, in fact, keeps confidential. *See* 5 U.S.C. § 552(b)(4). Disclosure of the confidential information could have a significant impact on Nokia's commercial operations by enabling competitors to have a better understanding of Nokia's future business plans and product development strategies, enabling such competitors to better compete against Nokia.

The confidential information includes information about Nokia that is clearly "commercial" in nature. *See Board of Trade v. Commodity Futures Trading Comm'n*, 627 F.2d 392, 403 & n.78 (D.C. Cir. 1980) (courts have given the term "commercial," as used in Section 552(b)(4), its ordinary meanings). In addition, the information voluntarily provided is "confidential." Under well-settled case law, such material "is 'confidential' . . . if disclosure of the information is likely to have either of the following effects: (1) to impair the government's ability to obtain necessary information in the future; or (2) to cause substantial harm to the competitive position of the person from whom the information was obtained." *National Parks and Conservation Ass'n v. Morton*, 498 F.2d 764, 770 (D.C. Cir. 1974) (footnote omitted); *see also Critical Mass Energy Project v. NRC*, 975 F.2d 871 (D.C. Cir. 1992), *cert. denied*, 113 S. Ct. 1579 (1993) (holding that voluntarily provided information is confidential for the purpose of FOIA Exemption 4 if it is a kind that would customarily not be released to the public by the person from whom it was obtained).

(4) Explanation of the Degree to Which the Information Concerns a Service that is Subject to Competition (Section 0.459(b)(4)).

Substantial competition exists between companies seeking Commission approval to operate as SAS Administrators and ESC Operators. Designated Administrators and Operators will compete vigorously to provide these services.

(5) Explanation of How Disclosure of the Information Could Result in Substantial Competitive Harm (Section 0.459(b)(5)).

The commercially sensitive information for which Nokia seeks confidential treatment includes proprietary and highly sensitive commercial information detailing technical information for new services being developed, product development strategies, future business plans and pricing methodologies. Such information is plainly sensitive commercial information that companies would normally keep confidential and that Nokia, in fact, keeps confidential. *See* 5 U.S.C. § 552(b)(4). Disclosure of the confidential information could have a significant impact on Nokia's commercial operations by enabling competitors to have a better understanding of Nokia's future business plans and product development strategies, enabling such competitors to better compete against Nokia. Under these circumstances, it is "virtually axiomatic" that the information qualifies for withholding under Exemption 4 of the Freedom of Information Act, *see National Parks and Conservation Ass'n v. Kleppe*, 547 F.2d 673, 684 (D.C. Cir. 1976), and under Sections 0.457(d)(2) and 0.459(b).

(6) Identification of Measures Taken to Prevent Unauthorized Disclosure (Section 0.459(b)(6)).

Nokia keeps this kind of sensitive commercial information confidential and does not make it publicly available.

(7) Identification of Whether the Information is Available to the Public and the Extent of Any Previous Disclosure of Information to Third Parties (Section 0.459(b)(7)).

None of the information for which Nokia seeks confidential treatment has been provided to the public.

(8) Justification of Period During Which the Submitting Party Asserts that the Material Should Not be Available for Public Disclosure (Section 0.459(b)(8)).

Nokia respectfully requests that the Commission withhold the information from public inspection indefinitely. Nokia would not, in the normal course of business, provide this information to the public.

Please contact the undersigned with any questions. Thank you for your assistance.

Respectfully submitted,

/s/ Jeffrey A. Marks

Jeffrey A. Marks

Enclosure

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of Wireless Telecommunications Bureau and Office of Engineering and Technology Establish Procedure and Deadline for Filing Spectrum Access System (SAS) Administrator(s) and Environmental Sensing Capability (ESC) Operator(s) Applications	GN Docket No. 15-319

Proposal to Operate As Spectrum Access Server Administrator and Environmental Sensing Capability Operator

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Proposal to Operate As Spectrum Access Server Administrator and Environmental Sensing Capability Operator

Pursuant to the Federal Communications Commission's ("FCC") Public Notice in the above-referenced proceeding ("*Public Notice*"), Nokia respectfully submits a proposal to operate as a Spectrum Access Server ("SAS") Administrator and Environmental Sensing Capability ("ESC") operator.

1 Introduction

Leveraging its deep knowledge of building reliable, large scale wireless networks, cloud infrastructure, and Self-Organizing Networks ("SON") capabilities, Nokia aims to provide a SAS and ESC solution that delivers best-in-class performance, is future-proof, and that helps realize the promise of the next generation of spectrum management within the United States. In this proposal, Nokia presents comprehensive information to support its request to operate SAS and ESC service required to enable rapid adoption of 3.5 GHz Citizens Broadband Radio Service ("CBRS") spectrum in commercial networks.

Nokia has a strong track record of pioneering research and technology development in the area of shared spectrum use in wireless networks. In June 2016, Nokia announced industry-first Citizens Broadband Service Devices ("CBSD") in the form new micro and indoor pico cells that are part of its industry leading, innovative Flexi Zone small cell product portfolio [1]. Nokia Technologies and Bell Labs have been actively performing advanced research in spectrum sharing for well over a decade [8-21] and have developed transformational technologies protected by approximately 80 patents. Nokia has participated in dozens of spectrum sharing projects across the globe, and its Bell Labs research team was the first to publicly report on the design of an end-to-end 3550-3700 MHz CBRS testbed and SAS prototype [8] and to showcase the development and live operation of Licensed Spectrum Access ("LSA") controllers throughout Europe. Nokia serves in leadership positions in the Spectrum Sharing Committee of Wireless Innovation Forum ("WInnForum") and has actively participated in the FCC's 3.5 GHz proceedings as well as other standards bodies relevant to spectrum sharing in other regions around the world.

Guided by our active participation in FCC and industry efforts in the development of 3.5 GHz CBRS Rules, our proposal conforms to requirements and rules outlined in the Order authorizing CBRS rules [2], the subsequent Order on Reconsideration and Second Report and Order on clarifications of CBRS rules and additional requirements [3], baseline industry consensus SAS requirements [4], WInnForum SAS-CBSD protocol [5], and SAS-SAS protocol [6].

The Nokia SAS development effort is rooted in the pioneering research on design of an end-to-end CBRS testbed and its key SAS component started in early 2014. This research was reported in IEEE DySPAN in October 2015 [8] and showcased in a recent public demonstration in IEEE Globecom 2016 [22]. Nokia's SAS system supports (a) CBSD registration and deregistration, (b) 3-tier spectrum access enforcement by dynamic vacating of active secondary users (*i.e*. CBSDs) and reassignment of users to other available CBRS channels in the event of the appearance of incumbents or Priority Access License ("PAL" users, (c) online notification of static or dynamic spatially and temporally constrained exclusion zones (from entities such as an ESC), and (d) interference calculations based on current industry standard propagation models. Starting with a Bell Labs designed SAS-CBSD protocol called Protocol for Tiered Access to Shared Spectrum ("PTASS"), the Nokia SAS has evolved to support the most recent WInnForum SAS-CBSD and SAS-SAS protocol. Nokia SAS leverages virtualization and cloud technologies to support unprecedented scalability, and it will evolve to support: (1) SAS-SAS information exchange, (2) a novel CBSD channel management technology – namely Nokia's Co-existence Aware Channel Management ("CACM"), (3) PAL Protection Area (PPA) specification and enforcement, and (4) a PAL subleasing marketplace. Building on its sound design foundation that provides for scaling computing, storage, and network bandwidth resources, Nokia anticipates it will seamlessly evolve its SAS to account for updates to CBRS rules in future FCC orders and evolving industry consensus on optimal functioning of the CBRS ecosystem.

1.1 Outline of the Nokia Application

In the following sections, this Application further elaborates how the Nokia SAS and ESC solution addresses requests and requirements set forth in Sections II, III and IV of FCC's *Public Notice.* Following the structure outlined in these Sections, the application is organized as follows: Section 2 provides a detailed overview of the (a) Nokia SAS and its capabilities and (b) Nokia ESC offering. Section 3 presents in detail the functional architecture of Nokia SAS and ESC. Section 4 and Section 5 provide details on operation of the SAS and ESC respectively.

2 Overview of Nokia SAS and ESC Offering

In the following, we first provide an overview of functions that Nokia SAS supports to comply with the requirements outlined in the 47 C.F.R Part 96 specifications, and then discuss those in detail in Section 2.2.1 to 2.2.14. Section 2.3 provides an overview of the ESC. Sections 2.4, 2.5 and 2.6 present details on Nokia's business structure, technical and management expertise and disclosure on Nokia's financial capability.

2.1 Nokia SAS Features

We have organized the Nokia SAS features into four distinct groups: (1) Guaranteeing Incumbent Protection; (2) CBSD Registration; (3) Channel Assignment and Management; and (4) PAL Protection.

Guaranteeing Incumbent Protection

1. When no ESCs are available, Nokia SAS will maintain and enforce static exclusion zones that have been already defined [7]. Enforcement will be as follows: (1) No CBSD whose location falls in the exclusion zone will be granted channels conflicting with incumbent use. (2) CBSDs in the proximity of the exclusion zone will be provided transmission power and channel assignments which guarantee co/adjacent channel interference on incumbent receivers meet required criteria.
2. Nokia SAS will provide tools that can help Government agencies with incumbent systems that may operate in CBRS bands in the future to specify transient or permanent exclusion zones that all SAS will enforce.
3. Nokia SAS will communicate with the ESC networks, such as the Nokia ESC, to acquire reports on activity of shipborne and ground-based radars in the CBRS band. In the event an ESC reports the presence of such radars, the SAS will identify and modify all CBRS operations that can interfere with the incumbent. Specifically, it will identify all active CBSDs whose channel of operation impacts the incumbent and relocate them to non-interfering channels or, in the worst case, idle them, consistent with PAL, GAA tier requirements.
4. Nokia SAS will also protect non-government Fixed Satellite Service ("FSS") earth stations, including grandfathered earth stations in the 3600-3700 MHz range and earth stations in the adjacent 3700-4200 MHz range (used for Telemetry, Tracking and Control ("TT&C")). Nokia SAS will provide tools to import information records of these systems from FCC databases and will provide specific protection tailored to the needs of each site owner.
5. Nokia SAS will protect grandfathered Part 90 users such as WISPs and utilities that currently use 3650-3700 MHz portion of CBRS bands. Specifically, it will follow guidelines developed by the FCC and any further refinements from WInnForum spectrum sharing working groups.
6. Nokia SAS will also fully support protection of systems deployed across Canada and Mexico borders that operate in 3550-3700 MHz bands.

CBSD Registration

Nokia SAS will support CBSD registration using procedures outlined in the WInnForum SAS-CBSD protocol for CBSDs deployed by individual device owners, professional installers and other forms of CBRS network operators. It will collect device identification information and authenticate using certificate schemes developed in the WInnForum and maintain record of various device parameters (*e.g.*, location, antenna characteristics, height, transmits power *etc*.).

Nokia SAS will support Transport Layer Security ("TLS") standard for SAS-CBSD protocol transactions over HTTPS protocol to guarantee secure communication between Nokia SAS and CBSDs.

Channel assignment and management

Nokia SAS will implement innovative channel assignment and management technologies collectively called Co-Existence Aware Channel Management ("CACM") which support the following salient features:

1. Supports *Spectrum Inquiry* and *Spectrum Grant* transactions in the WInnForum SAS-CBSD protocol and thus allow CBSDs to query the SAS to obtain information about available CBRS channels.
2. Guarantees non-interfering channel assignments to CBSDs that belong to different assignees (*e.g.*, different operators) or network groups (*e.g.*, different groups of CBSDs, each of which has many CBSDs that can operate co-channel) that need different PAL channel assignments.
3. Supports co-existence aware grouping of GAA devices that support Media Access Control ("MAC") level co-existence (*e.g.*, using Listen-Before-Talk ("LBT")).
4. Allocate independent channels whenever possible to individual CBSDs or CBSD groups exploiting interference relationships between them based on known CBSD parameters disclosed during registration (such as location, transmission power, antenna characteristics) and amount of spectrum requested.
5. Support for GAA CBSDs that do not support MAC with co-existence features.

PAL protection

Nokia SAS will maintain a database of auctioned PALs and guarantee that (a) CBSDs registering and requesting channels against valid PALs receive exclusive channels and (b) the associated PAL interference protection rights are guaranteed. Specifically, Nokia CACM technology models interference relationships, using propagation models and tools recommended in WInnForum requirements and, optionally, further enhanced by Nokia, to guarantee exclusive channels.

When the SAS grants a CBRS channel to an authorized PAL CBSD, it will guarantee that GAA CBSDs currently using that channel are vacated and granted channels do not conflict with the PAL assignment.

Nokia SAS will also provide tools that enable the PAL owner to specify geographical areas called PAL Protection Areas ("PPAs") (that are smaller than PAL coverage areas) where a PAL owner deploys CBSDs and needs interference protection to be guaranteed. It will allow PAL areas left over after accounting for all component PPAs to be opened for subleasing.

Nokia SAS will also receive information about subleased PALs from peering SASs and respond to CBSD channel grant requests presenting the subleased PAL credentials.

2.2 Compliance of Nokia SAS with Part 96 Specification

In the following, we describe in detail how Nokia SAS will conform to requirements outlined in the FCC Part 96 rules as well as extended requirements set forth in the WInnForum SAS requirements document [4].

2.2.1 *Information Gathering and retention (47 C.F.R.§96.55)*

Nokia SAS will strictly adhere to requirements on information gathering and retention outlined in the FCC rules.

- Nokia SAS will maintain current information on registered CBSDs, the geographic locations and configuration of protected FSS locations as set forth in section 96.17 of the FCC's rules, and the federal Incumbent User Exclusion Zones and Protection Zones set forth in section 96.55 of the FCC's rules.
- For registered CBSDs, Nokia SAS will maintain all information required by sections 96.39 and 96.45 of the FCC's rules. Specifically, parameters such as location (latitude, longitude data), device category (Category A/B), antenna characteristics (*e.g.*, gain, beam width), installation parameters (*e.g.*, height), maximum transmit power, type of baseband supported, FCC assigned ID, call sign, manufacturer's serial numbers and current channel grants, if any. It will also store WInnForum SAS-CBSD specific parameters such as heartbeat period and status of the last received heartbeat and information specific to device ownership and device owner contact information. Nokia SAS will process and retain acknowledgements by all entities registering CBSDs that they understand the risk of possible interference from federal Incumbent User radar operations in the band. [4, 96.55].
- When FCC PAL auctions conclude and data about successfully auctioned PALs is available, Nokia SAS will acquire and store such data. Specifically, it will store information about the PAL owner, its issuance and expiration dates, and authorized census tract.
- Nokia SAS will make all information necessary to effectively coordinate operations between and among CBSDs available to other SAS Administrators.
- Nokia SAS will make CBSD registration information available to the public but will obfuscate the identities of the licensees providing the information for any public disclosures.
- For non-federal Incumbent Users, Nokia SAS will maintain a record of the location of protected earth stations as well as registration information required by section 96.17 of the FCC's rules.
- Nokia SAS will maintain records not pertaining to federal Incumbent User transmissions for at least 60 months [4, 96.55].
- Nokia SAS will only retain records of information or instructions received regarding federal Incumbent User transmissions from the ESC in accordance with information retention policies established as part of the ESC approval process [4, 96.55].
- Nokia SAS will directly interface with any necessary FCC database containing information required for the proper operation of the SAS [4,96.55].
- Nokia SAS will not have any connectivity to any military or other sensitive federal database or system and will not store, retain, transmit, or disclose operational information on the movement or position of any federal systems. Nokia SAS will support policies that include appropriate safeguards for classified and other sensitive data that the FCC will develop in coordination with the National Telecommunications and Information Administration ("NTIA") and the Department of Defense ("DoD") [4, 96.63n & para 330].
- *SAS-to-SAS information exchange*: Nokia SAS will interoperate with all available and known SAS servers reachable on the public internet over secure connection using the WInnForum SAS-SAS protocol.

2.2.2 *Registration, Authentication and Authorization of CBSDs (47 C.F.R.§96.57)*

Nokia SAS will support following CBSD authentication, authorization and registration functions:

1. Prior to allowing a CBSD to register and request channel grants, Nokia SAS will authenticate the CBSD and its owner credential using the consensus process developed within WInnForum. Specifically, it will validate the device certificate (guaranteeing certified software) issued to device manufactures from the WInnForum-maintained Certificate Authority. The TLS session between the SAS and the CBSD that employs the device and server certificates guarantees mutual authentication for every SAS-CBSD transaction.
2. Once authenticated, Nokia SAS will receive the FCC identifier ("FCC ID") of any CBSD seeking access to its services in the registration request and verify that it is valid prior to authorizing service access. It will obtain a list of devices with valid FCC IDs from the FCC's Equipment Authorization System. To ensure that it has the most up to date list, it will download this list on a regular basis.
3. CBSDs composed of a network of base stations may employ a Domain Proxy ("DP") for aggregating and communicating all required information exchanges between SAS and CBSDs. This architectural element is incorporated in the WInnForum reference architecture for CBRS ecosystem to facilitate efficient support of CBSDs that may have to be deployed in a private or firewalled network (*e.g.*, private enterprise) [4]. Therefore, Nokia SAS will support interfacing to a DP via WInnForum SAS-CBSD protocol message aggregation feature. It will rely on a certificate-based scheme outlined above to authenticate DP.
4. Nokia SAS will not authorize operation of CBSDs within Protection Zones except as set forth in section 96.15.
5. Nokia SAS will calculate and enforce PAL Protection Areas (PPAs) consistent with section 96.25.

2.2.3 *Frequency/Channel Allocation for CBSDs (47 C.F.R. §96.59)*

[redacted]

2.2.4 *Security of Communication (47 C.F.R §96.61)*

The Nokia SAS implementation will strictly meet the security requirements imposed in Section 96.61 of the FCC's rules as follows:

- Nokia SAS will employ standard security protocols mandated in the industry consensus developed in the WInnForum Spectrum Sharing group. Specifically, at the minimum, it will support TLS v1.2. We will support TLS v1.3 when that standard is finalized. This industry standard supports dynamic per session encryption key derived after two endpoints authenticate each other using trusted certificates based on public-private key cryptography. Nokia SAS will support various configurable cipher suites to offer the best-in-class, state-of-the-art security solution. The authentication and dynamic session encryption in TLS guarantees that third parties snooping on any communication to and from SAS cannot decrypt it.

- Access to Nokia SAS services available via web interfaces will support role based authenticated access for entities accessing its various services such as spectrum analytics, administration, operations, spectrum subleasing and user account management. Such role based authenticated access guarantees that unauthorized parties cannot access or alter the SAS or the information it presents to a user or a CBSD.
- Nokia SAS will rely on US NSA-grade encrypted file/data storage to store critical and sensitive data such as CBSD ownership information, information received from ESCs on incumbent activity to guarantee incumbent protection, activity of PAL CBSDs, *etc*., to guarantee stored data is protected from unauthorized data insertion or alteration.
- Nokia SAS will not provide service to a CBSD that cannot provide a verifiable FCC ID. To achieve this, SAS will retrieve from FCC databases all identification numbers of all FCC certified CBSDs and cross-check with the identity that the CBSD presents during device registration.

2.2.5 *Requirements for SAS Administrator (47 C.F.R. §96.63)*

Nokia SAS will conform to all requirements imposed in Section 96.63 of the FCC's rules. Specifically, the Nokia SAS will:

- Maintain a regularly updated database that contains the information described in section 96.55 [3].
- Establish a process for acquiring and storing in the database necessary and appropriate information from the FCC's databases, including PAL assignments, and synchronizing the database with the current FCC databases at least once a day to include newly licensed facilities or any changes to licensed facilities.
- Establish and follow protocols and procedures to ensure compliance with the rules set forth in this part, including the SAS functions set forth in section 96.53 [3].
- Establish and follow protocols and procedures sufficient to ensure that all communications and interactions between the SAS, ESC, and CBSDs are accurate and secure and that unauthorized parties cannot access or alter the SAS or the information transmitted from the SAS to CBSDs.

In addition:

- Nokia intends to provide SAS and ESC service for a five-year term.
- Nokia SAS team will respond in a timely manner to verify, correct or remove, as appropriate, data if the FCC or any party brings a claim of inaccuracies in the SAS to its attention.
- Nokia SAS will work within industry bodies such as WInnForum to develop a standardized process for coordinating operations with other SASs, avoiding any conflicting assignments, maximizing shared use of available frequencies, ensuring continuity of service to all registered CBSDs, and providing the data collected pursuant to section 96.55 [3].
- Nokia SAS will coordinate with other SAS Administrators including, to the extent possible, sharing information, facilitating non-interfering use by CBSDs connected to other SASs, maximizing available GAA frequencies by assigning PALs to similar channels in the same geographic regions, and other functions necessary to ensure that available spectrum is used efficiently consistent with this part.

- Nokia SAS will provide a login profile on its SAS web page to make non-federal, non-proprietary information available to the public using a web-based presentation framework in conformance with the CBRS rules.
- The Nokia SAS team will:
    - Ensure that the SAS shall be available at all times to immediately respond to requests from authorized FCC personnel for any and all information stored or retained by the SAS.
    - Establish and follow protocols to respond to instructions from the President of the United States, or another designated Federal government entity, issued pursuant to 47 U.S.C. § 606.
    - Establish and follow protocols to comply with enforcement instructions from the FCC.
- Nokia SAS will operate without any connectivity to any military or other sensitive federal database or system, except as otherwise required.
- Nokia SAS will not store, retain, transmit, or disclose operational information on the movement or position of any federal system or any information that reveals other operational information of any federal system that is not required by this part to effectively operate the SAS.

2.2.6 *Protection of PAL operators*

Nokia SAS will rely on PAL protection concepts developed within WInnForum as industry consensus. Specifically, Nokia SAS will provide tools to PAL owners to specify PPAs around their CBSD deployments on a dynamic basis and include the capability to dynamically adjust "spatial protection buffer" in the PPA as a multipoint polygon. The Phase I of deployment of our SAS will support computation of CBSD coverage, (claimed) PPA and Maximum Allowable PPA Claim area using baseline NTIA recommended propagation models which will be improved in Phase II using more refined propagation and computation techniques. In addition, in Phase II, event measurement data from CBSD can be leveraged to calculate GeoKPIs and fed into the SAS to further refine the calculated PPA.

2.2.7 *Network Sharing and Channel Management*

The network sharing configurations (also known as neutral host configurations) wherein a single CBSD supports multiple carrier channels, potentially one or more per operator, require that CBSD can acquire spectrum grants for each radio interface. Given it is unlikely that the first generation CBSDs will support tunable channel filters, configuring multiple carrier channels in a CBSD requires special care. It may be essential that, if a CBSD is using PALs of multiple operators to obtain carrier channels, the channels assigned to these PALs be sufficiently far apart (by at least 10 MHz) to avoid significant adjacent channel interference and that their Transmit/RX schedules be completely synchronized to minimize interference. The Nokia SAS will account for these requirements when processing channel requests from such multi-carrier CBSDs used in network sharing deployments.

2.2.8 *International Cross-border Protections*

Nokia has been providing coordination services to operators worldwide. Europe is a good example where we have to deploy across multiple borders. In the Americas region, we recently helped NTIA, FCC, the Mexican regulator and operators on both sides of the USA/Mexico border coordinate deployment of

700 MHz systems. The USA and Mexico are not using the same 700MHz band plan, resulting in various interference issues.

The Nokia SAS will follow FCC-provided guidance on zones along the Mexican and Canadian borders that will be excluded for CBSD operation to protect cross-border incumbents. It can make information on cross-border incumbent protection available via (1) a Graphical Front end, and (2) in the form of listing of the set of multiple endpoints of a smallest circumscribing polygon.

2.2.9 *PAL Subleasing*

The Nokia SAS will provide a web based tool for entities interested in subleasing PALs in sub-areas of a census tract to specify their PPA and submit applications to the SAS. We anticipate the format of PPA applications to be standardized by industry consensus.

Nokia SAS will provide map-based graphical tools (Figure 1) to display auctioned PALs, their census tracts and to specify PPAs within those census tracts. The tool will provide access to the following capabilities to users with appropriate rights:

- Display existing and active PPAs and CBSDs operational within a PPA.
- Indicate new PPA sub-areas in PAL coverage via Polygon and other graphing tools.
- Associate owner information with PPA.

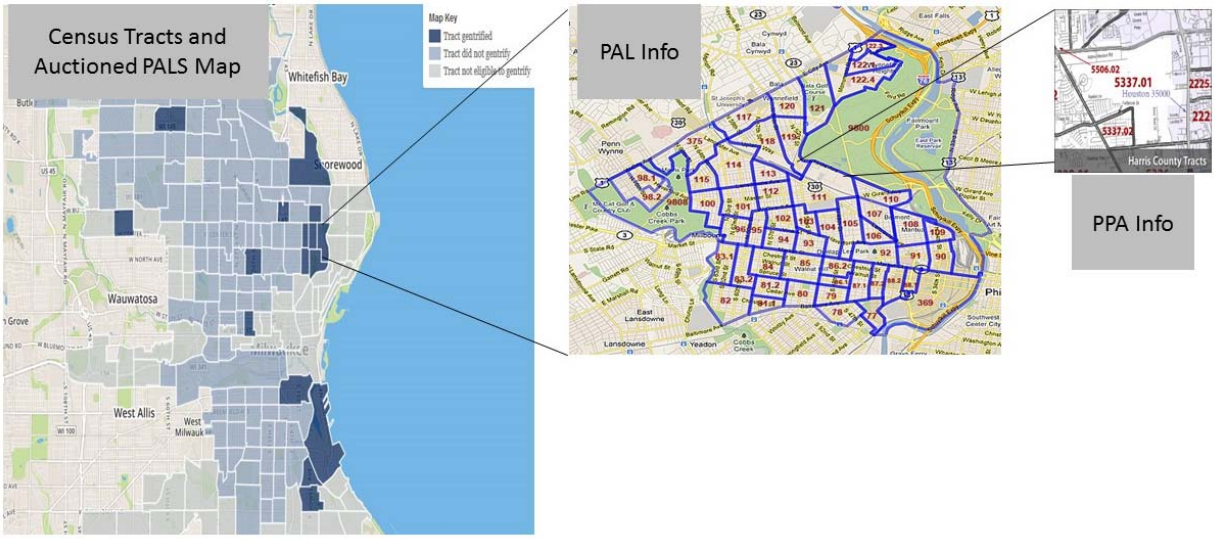


Figure 1: PAL spectrum secondary market: PAL subleasing (Representative rendering from web images)

The tool will use propagation modeling and CBSD registration information to predict coverage of active CBSDs mapped inside a PPA and compute and display aggregate coverage of all active CBSDs in the PPA in relation to the PPA's coverage. In case there are discrepancies in the aggregate coverage of CBSDs inside a PPA and specified coverage of the PPA, the tool will offer the option to reconcile the two by (1) either reducing CBSD coverage by transmit power reduction or (2) readjusting PPA coverage specification.

The Nokia SAS will support PAL subleasing beyond PPA in a PAL boundary. It will provide a PAL subleasing service where it will allow parties interested in subleasing to (1) search spatial regions of interest for available PALs, (2) provide price information, if available, from a PAL owner, (3) select PALs to request subleasing, and (4) provide information on original PAL credentials and sublease tokens that capture sublease owner information and spatial region of validity via secure channel to the sublessee.

Lessee must be able to provide credentials that can be verified against an FCC or industry-maintained database before a sublease can be granted. We expect the burden of vetting the sublessee to be met when sublessee credentials are verified and entered in the said database.

The Nokia SAS can serve as a lease broker between PAL owners and parties interested in PAL subleases. It can leverage public-private certificate-based message digests to sign granted subleases which must be included in the requests for PAL spectrum grants. Nokia is also exploring use of distributed blockchain technologies in building the subleasing tools.

2.2.10 *Nokia SAS Feature Upgrades*

Nokia innovations such as CACM are designed to handle device baseband diversity – *i.e.*, a mix of devices supporting different flavors of LTE from the start. Also, CACM can handle an arbitrary evolving mix of PAL and GAA devices in a region without requiring significant changes. Therefore, Nokia envisions its SAS will maintain backward compatibility to support diverse baseband functionalities as they evolve.

Nokia is an active participant in WInnForum and holds leadership positions in its working groups. It plays a major role in continuous evolutionary development of CBRS protocols and methods. Given this, we expect our SAS product team to be continuously cognizant of new requirements and be able to support as per customer priorities.

Specifically, Nokia SAS will support new versions of SAS-SAS and SAS-CBSD protocol that will emerge from industry forums like WInnForum. Support for legacy versions of CBSD and SAS protocols still deployed in the field will be maintained.

2.2.11 *Tools for Single CBSD Owner and Network Owners*

WInnForum SAS-CBSD protocol, which Nokia SAS will support, requires a single CBSD or a group of CBSD owners to have an account with the SAS provider(s). We envision that the device owner can access information about the CBSDs registered as a part of the account. For example, the user can access historical information such as the CBRS channels assigned and any device-reported metrics, like throughput, packet loss, delay, and interference metrics.

If the CBSD group is of a size that may qualify to request a PAL sublease, such PAL leasing and PPA tools will be made available.

Nokia SAS will support interfacing to individual CBSD as well as to Nokia or third party Domain Proxy (“DP”). If the CBSD is behind a DP, it will be configured by an administrative process to automatically register with the DP. Our SAS will also provide tools to import CBSD information associated with an owner account from multiple data sources (*e.g.*, Microsoft Excel spreadsheets, tab limited text files, *etc*.)

2.2.12 *Service level guarantees from Nokia SAS*

Nokia SAS implementation relies on two scaling mechanisms to support tens of millions of CBSDs: (1) Vertical scaling: Here, the CBSD registration traffic over a large region is dynamically distributed to multiple data centers using a DNS forwarder mechanism. For example, Nokia SAS may use four data centers – one dedicated to handling CBSDs in the entire northeast of the USA, the other handling devices in the southeast, and so on. (2) Horizontal scaling: Each SAS instance within a data center achieves scalability by using a load balancer combined with a large number of virtual machines ("VMs") (or Docker Containers ("DCs") handling various SAS functions such as SAS-CBSD and SAS-SAS protocol instances, compute engines (*e.g.*, interference computation, CACM engine), user interface and scalable database.

Given this architecture, service reliability is achieved in two ways:

First, in case of large scale failure of an entire data center, we achieve service reliability by using dynamic DNS redirection to temporarily redirect CBSDs to active data centers and dynamically allocating more network capacity and data center resources (*e.g.*, VMs, storage). Within a single datacenter Nokia SAS cloud based architecture provides configurable levels of redundancy depending on the criticality of the SAS function. For example, SAS-CBSD, SAS-SAS, SAS-ESC protocol instances and databases can be configured to run in a 1+1 mirror configuration, guaranteeing rapid recovery. Second, for other non-critical functions like UI or the CACM engine, we achieve reliability by dynamically reassigning operations to secondary VMs (or DCs) in the data center pool.

Nokia's Managed Services Business manages large scale networks worldwide that collectively offer network services to hundreds of millions of users and has earned the trust of major Tier-1 customers around the world. We have a large team of engineers with extensive experience dedicated 24/7 to provide a rapid response in the event of large scale failures. We anticipate a similar level of service for the SAS product or service deployments for CBRS operators.

2.2.13 *Nokia SAS Administrator Fees (47 C.F.R §96.65)*

Nokia is seeking to establish the business model that best addresses the market needs for the exciting new CBRS space. Nokia is presently considering the following models:

[redacted]

[redacted]

2.2.14 *Data exploitation and Nokia SAS*

If the SAS is implemented as a multi-client SAS, it will have extensive information about the CBRS networks of multiple operators. Specifically, it will collect information about the spatial characteristics of CBSD deployment and network performance metrics such as configured capacity, spectrum utilization, traffic loading, left over capacity and user density as a function of time. [redacted]

2.3 Nokia ESC Overview

The Nokia ESC consists of two parts: (1) the Nokia ESC Sensor Network; and (2) the Nokia ESC Cloud.

The ESC Sensor Network is a network of radio frequency ("RF") sensors that continuously acquire, digitize and analyze on-the-air transmissions collected in the 3400-3800 MHz range. This network will be deployed in the exclusion zones defined along the USA East, West and Gulf coasts, and gradually densified. Nokia may leverage its unique relationships with Tier-1 as well as Tier-2/3 network operators to build and manage this network.

The ESC network will maintain redundant, reliable, and secure connection to the Nokia ESC Cloud, which will collect, combine and analyze the sensor data. The ESC Cloud provides an authoritative decision on appearance of incumbent radar and makes this information available via secure connection to the Nokia SAS. The Nokia ESC cloud will leverage TLSv1.2 over HTTPS to provide industry-standard secure connectivity and will implement future WInnForum standardized SAS-ESC protocol when one becomes available.[1] It will securely store information about incumbent detection and departure events and communications with SAS for conveying such detected events and make the information available to regulators such as the FCC, NTIA and any government entity and agency with provable privilege to access such information. Nokia believes the Nokia ESC Sensor and ESC Cloud architecture is future proof in that it can support new types of incumbents via software upgrades and additional spectrum bands with inexpensive upgrades to sensor hardware.

Nokia believes an ESC certified to meet performance criteria such as accurate detection of absence or presence of incumbents, security of SAS-ESC communications and 24/7 reliability is an essential and trusted component in guaranteeing incumbent protection. In the event an ESC fails, a certified SAS converts dynamic protection zones to static exclusion zones and enforces them to guarantee incumbent protection. Therefore, we do not foresee any conflict of interest in Nokia operating both SAS and ESC, as the objective of successful secondary use of CBRS spectrum is always secondary to protection of incumbent systems and this is guaranteed via successful certification of both entities.

2.4 Nokia Business Structure

Nokia is a public limited-liability company listed on the Nasdaq Helsinki, Euronext Paris and New York Stock Exchange. A truly global company, we are 160 nationalities working in more than 100 countries. Nokia's reported revenue for the 2016 year was EUR 23.61 Billion. Some of the key world markets and Tier-1 customers Nokia serves are (a) *North America*: Verizon, AT&T, T-Mobile, Sprint, USCC, regional operators, and public sector customers. *(b) Latin America:* América Móvil, AT&T, Oi, Telefónica, Telmex and Tim. *(c) Europe:* Deutsche Telekom, MegaFon, MTS Sistema, Orange, Telefónica, TeliaSonera and Vodafone Group. *(d) Asia-Pacific:* KDDI, KT, LG Uplus, NBN Australia, NTT DoCoMo, Singtel, SK Broadband, SK Telecom, Smartfren, SoftBank, Spark, StarHub, Telekom Malaysia, Telkom Indonesia, Telkomsel, VNPT and Vodafone *(e) Greater China:* China Mobile, China Telecom, China Tower and China Unicom, and public sector customers. *(f) Middle East and Africa:* Airtel, du, Etisalat, Maroc Telecom, Mobily, MTN, Ooredoo, Orange, OTA Djezzy, Smile, STC, Telkom, Vodacom and Zain.

[1] If an industry standard SAS-ESC protocol is finalized, the Nokia ESC Cloud can supply incumbent information to other SASs in the CBRS ecosystem as well.

Nokia is organized into 5 business groups: *the network business*: (1) Mobile Networks (2) Fixed Networks (3) IP/Optical Networks and (4) Applications & Analytics and (5) Nokia Technologies. For more information about Nokia, please visit our public web site: http://www.nokia.com/en_int/about-us.

2.5 Technical and Management Expertise

Nokia is a global leader in creating the technologies at the heart of our connected world. Powered by the research and innovation of Nokia Bell Labs, we serve communications service providers, governments, large enterprises and consumers, with the industry's most complete, end-to-end portfolio of products, services and licensing.

From the enabling infrastructure for 5G and the Internet of Things, to emerging applications in virtual reality and digital health, we are shaping the future of technology to transform the human experience. We combine global leadership in mobile and fixed network infrastructure, with the software, services, and advanced technologies to transform how smart devices and sensors tap the power of connectivity.

Nokia has assembled a core team of spectrum sharing experts. Nokia is in the process of building upon this core team to assemble a team of 30 members including Bell Labs researchers, Standards SMEs (WInnForum, and CBRS Alliance), systems engineers, software architects, software developers, project managers and system testers for the development of its SAS solution. Biographies of some of the members of the Nokia technical team for its spectrum sharing program are listed below.

Stephan Litjens, VP of Nokia Innovation Steering and General Manager, DAaaS Business Unit

Stephan is the Vice President of Nokia Innovation Steering and General Manager of Digital Automation as a Service (DAaaS) Business Unit in Nokia. His responsibilities include innovations both internally and externally with customers, partners, and governments to achieve Nokia's ambition to create the Programmable World. Prior to his current role, Stephan was responsible for Nokia's Mobile Broadband portfolio strategy. Stephan joined Nokia in 1997 and has held several R&D, product marketing, services, product support and portfolio / product management and leadership positions in the mobile networks business. During the rise of 3G in the early 2000s, Stephan moved to Finland from the Netherlands. Since then he has been working for Nokia in Germany and in Japan before moving back to the Nokia headquarters in Espoo, Finland. He is enthusiastic about exploring opportunities, new ways of working and business prospects that can make a difference and inspire others.

Dr. Milind M. Buddhikot, Distinguished Member of Technical Staff (DMTS), Nokia Bell Laboratories

Milind M. Buddhikot is currently a Distinguished Member of Technical Staff ("DMTS") in Nokia Bell Laboratories, where he conducts research in next generation of wireless networks. In a research career spanning 22+ years, he has made significant contributions, scientifically as well as to the business aspects of wireless, IP and multi-media networking.

Milind's recent work is in the area of high capacity wireless networks, in particular on topics of exploitation of shared spectrum via dynamic spectrum access ("DSA") technologies and policy-driven multiband spectrum aggregation. He has authored 47+ technical papers and holds 16+ US or international patents, some of which are in the key areas of spectrum sharing and aggregation. Per Google Scholar,

Milind's research publications have recorded 6300+ citations and are well recognized within the research community. Three concepts he pioneered and researched, namely the concept of database coordinated dynamic spectrum access (2004), ultra-broadband small cells using shared spectrum (2009) and policy driven multiband spectrum aggregation (2012), have now emerged as promising technology and spectrum policy directions.

Milind has been co-founder and chief architect of two wireless technology ventures and has successfully transitioned assets created in his research projects to business divisions. Milind is a co-founder of the IEEE DySPAN symposium, a premier conference on the topic of Dynamic Spectrum Access. Milind has served as a member of the Steering Committee of the WInnForum Spectrum Sharing Working Group and as a member of WInnForum working groups WG1, WG3. In the recent past, he has also served as the Co-chair of FCC TAC Working Group on Future Unlicensed Services (2015) and as a member of FCC TAC Working group on Future Spectrum Sharing and Chair/coordinator of DySPAN Steering Committee (2012-2015).

Dr. Ir. Michael Peeters, Head of Innovation Portfolio Management for Nokia

A passionate leader with a background in both research and strategy, Dr. Ir. Michael Peeters is Head of Innovation Portfolio Management for Nokia. Michael has been identifying and implementing industry opportunities through a career that spans two decades and technology disciplines.

Previously as CTO for the Wireless Division at Alcatel-Lucent, he led a team with responsibility to see beyond the business analysis and help customers envision how emerging technologies and trends will impact their networks and end-user community. The shaping and approach to vRAN and 5G were two of his team's key responsibilities.

Prior to his role as CTO for the Wireless Division, he was CTO for the Wireline Division of Alcatel-Lucent. During this tenure, he helped the business commercialize VDSL2 Vectoring, an idea conceived seven years earlier while Michael led the Bell Labs Access Nodes and DSL Technology Group.

He has authored more than 100 peer-reviewed publications, many white papers and holds patents in the access and photonics domains. Michael earned a Ph.D. in Applied Physics and Photonics from Vrije Universiteit Brussel as well as a master's degree in Electrotechnical Engineering.

Dr. Mohammad R. Khawer, Radio and Platform Innovation Leader, Nokia Mobile Networks CTO

Mohammad R. Khawer possess a track record spanning two decades at Nokia (former Alcatel-Lucent, and Lucent Technologies), of leading high performance global engineering teams and collaborating with Bell Labs research, to commercialize cutting edge wireless base-station products. His current responsibilities include collaboration with the Bell Labs research and the product/solutions teams to accelerate transfer of applied research ideas into next generation commercial Nokia products. Nokia Spectrum Controller ("NSC") providing the SAS capability is one such key initiative he is leading in collaboration with Bell Labs and the Nokia CIOO Innovation Steering team.

Mohammad has also been actively involved in the applied research work associated with LTE deployment in the Unlicensed Spectrum (LTE-U/LAA/MULTEFire) and its fair co-existence with Wi-Fi. His research in this domain has resulted in several IEEE publications, LTE-U Forum, and 3GPP LAA technical contributions that are backed by over 20 filed patents in the last two years.

Mohammad currently holds 30+ US and international granted patents, and has a Ph.D. and M.S. in Computer & Information Science Engineering (CISE) from Syracuse University, New York, USA.

Prakash Moorut, Nokia North America Spectrum Lead

In this role, Prakash is responsible for working with regulators, operators and industry members to open more useable Commercial Mobile Broadband spectrum in North America. He has over 19 years of experience working in Europe and the USA on major communications systems, and is currently enabling Small Cells, 5G technologies and Spectrum Sharing. He also has extensive experience in spectrum regulation and strategy, standardization, spectrum coexistence analysis/simulations and developing efficient spectrum usage solutions. He is the Co-Chair of Working Group 3 (Protocols) in the WInnForum Spectrum Sharing Committee. Before joining Nokia, he worked for Motorola where he created and led a customer facing spectrum engineering group located in USA, France, and China. He has several publications and patents related to spectrum usage. He received his MSEE degree from "Ecole Supérieure d'Electricité" (SUPELEC) in Paris, France.

Seppo Yrjölä, Nokia Sr. Principal Innovator

A passionate innovator with a background in research, strategy and business, Seppo Yrjölä is Sr. Principal Innovator at Nokia. Seppo has been with Nokia for 28 years, and has worked onNokia cables, which was a backbone of Nokia for many years before wireless. During the next ten years at Nokia Mobile Phones and Industrial Electronics (LK-Products) his passion was to make radios happen for the 1st and 2nd generation mobile systems holding a variety of positions from researcher to R&D and business management. Around 18 years ago, technological challenge and opportunities in 3G networks inspired him to join Nokia Networks R&D where he led 4G wireless technology research. During the Nokia Siemens Networks merger, he took a new challenge in the Innovations team to scout for the best technology-driven business adventures and incubating them with customers and partners into NSN success stories. His current focus is on scouting disruptive innovations in the area of future radios with cognitive radio business. Seppo leads Nokia's current spectrum sharing research and field trials in Finland, Italy and Russia, engaged with local governments, academia and ecosystems. He holds a master's degree in electrical engineering from the University of Oulu and has done postgraduate studies in telecommunication and radio technology. He has authored 40+ peer-reviewed publications, and holds multiple patents in the radio domain.

Al Jette, Head of North America Industry Environment

Al Jette is the Head of North American Industry Environment for Nokia. Al has been working in the wireless telecom industry since 1989 and has been directly involved in all current major cellular technologies for the past 28 years. Al is currently on the WInnForum Board of Directors, co-chair of WInnForum Spectrum Sharing Committee, WG1 (Functional and Operational Requirements), and chair of CBRS Alliance Technical Working Group. Besides working in standards for the past 18 years, Al has held various positions in the telecommunications industry including: system engineering, development and system testing. Prior to working in the telecom industry, Al worked for Westinghouse and Northrop on RADAR and Electronic Countermeasure systems. Al holds a MS degree in Electrical Engineering from Illinois Institute of Technology and a BS in Computer Engineering from Cornell University.

Jeffrey A. Marks, Senior Counsel – Director, Policy and Regulatory Affairs

Jeffrey Marks is Senior Counsel – Director, Policy and Regulatory Affairs for Nokia. In that role, Jeff develops and presents Nokia's public policy positions to policymakers at all levels of government. Jeff has over 15 years of legal and policy experience navigating issues faced by information and communications technology companies. For Nokia, Jeff advocates on a wide range of issues, including spectrum policy, net neutrality/net governance, public safety communications, privacy, cybersecurity, broadband infrastructure deployment, and transition to all-IP networks. He earned his B.A. in Government from Franklin and Marshall and his J.D. from The George Washington University Law School, where he graduated with High Honors.

Dr. Mike Dolan, Member of Technical Staff (MTS), Bell Labs

Mike Dolan represents Nokia in both the WInnForum and CBRS Alliance. He is the editor and rapporteur of the WInnForum SAS-CBSD protocol specification. He is active in establishing and improving the technical protocols that make the sharing of spectrum possible. He began his work in mobile networks over 30 years ago with the Phase 1 specifications for GSM. From there, Mike moved to CDMA and became the editor and rapporteur of the major CDMA RAN protocol specification. With the advent of LTE, he became the editor and major contributor to the 3GPP2 specification that bridged the CDMA world into LTE, providing an evolution path for 2G/3G CDMA operators into 4G LTE. Mike holds a PhD in Computer Science from the Illinois Institute of Technology.

Eamonn Gormley, Nokia Head of SON Architecture

Eamonn has over 20 years of leadership and expertise in the development and deployment of wireless communications systems, with a strong focus on Self Organizing Networks, OFDM wireless systems engineering, wireless algorithm design and simulation, signal processing, and software development. Eamonn serves as Head of SON Architecture at Nokia. Prior to Nokia, Eamonn was Chief Technology Officer at Eden Rock, where he led the initial design and development of the industry leading Eden-NET SON product, and led the technology team responsible for SON algorithm design, simulation and validation, operator SON solutions (GSM, UMTS, LTE), SON for spectrum sharing, management of the Eden Rock IP portfolio and industry standardization activities. Eamonn has been granted forty-three US patents in the area of wireless communications, with over fifty patents pending. He holds a B.Eng. degree in Electrical Engineering from the University of Limerick, Ireland.

Charles Immendorf, Nokia Head of SON Strategy

Charles is a veteran of the wireless industry with demonstrated leadership in the development and deployment of advanced software solutions and a track record of high-value innovations. Charles serves as Head of SON Strategy at Nokia. Prior to Nokia, he was the Co-founder, CEO and board member of Eden Rock Communications where he led Eden Rock from its inception to the industry leader in Self Organizing Networks (SON) software solutions. Under his leadership, Eden Rock developed a breakthrough SON solution, produced over 80 issued/pending patents, established a highly-satisfied mobile operator customer base, generated substantial revenues, and established advanced research projects with the United States Department of Defense. From 2001-2007, Charles led substantial R&D programs, aided the successful deployment of large wireless commercial networks globally, and served in an executive capacity for mid-sized RAN OEMs. From 1995-2001, Charles served at AT&T as the Director of Software Development for AT&T for one of the earliest applications of 4G OFDM for commercial broadband wireless. He holds a BS

in Electrical Engineering with highest honors from Rutgers University College of Engineering in New Jersey.

Jake Yun, Nokia Principal Systems Engineer

Jake has over 17 years of experience in research and development of 4G systems including Mobile WiMAX and LTE systems. His experience includes OFDM-MIMO baseband signal processing algorithm development, link level and system level simulation platform development, and Self Organizing Network (SON) algorithm development. Jake was part of a spectrum sharing research team and contributed to the joint project with Lockheed Martin for SSPARC (Shared Spectrum Access for Radar and Communications) program at DARPA. Jake additionally serviced on the spectrum sharing projects with the US Office of Naval Research and the Mexico Federal Telecommunications Institute (IFT). He also attended and contributed to standard bodies such as IEEE 802.16 working group and WiMAX Forum technical working groups from 2004 until 2009. He is currently a Principal Systems Engineer at Nokia. Prior to Nokia, Jake was a Principal Systems Engineer at Eden Rock Communications. He was Eden Rock's delegation for NGMN and Small Cell Forum activities and contributed to the NGMN small cell working group with the recommended practices of the Centralized-SON for multi-vendor HetNet operation. He received Ph.D. degree in Electrical Engineering from Pennsylvania State University in 2004.

Rekha Menon, Nokia Principal Systems Engineer

Rekha has over 13 years of research and development experience in Wireless Communications with a strong focus on Optimization techniques for wireless systems, Spectrum Sharing techniques, Cognitive Radio technologies, OFDM systems and MIMO systems. Rekha is a Principal Systems Engineer at Nokia. Prior to Nokia, she was a Principal Systems Engineer at Eden Rock Communications where she was part of a research team focused on developing SON based techniques for effective spectrum sharing between legacy government communication systems and commercial LTE systems. Rekha was part of a spectrum sharing research team and contributed to the joint project with Lockheed Martin for SSPARC (Shared Spectrum Access for Radar and Communications) program at DARPA. Rekha additionally served on the spectrum sharing projects with the US Office of Naval Research and the Mexico Federal Telecommunications Institute (IFT). She is currently part of the systems Engineering team that develops SON solutions for optimizing commercial wireless networks. Rekha received her Ph.D. in Electrical Engineering with a focus on Wireless Communications from Virginia Tech in 2007. She has published numerous journal and conference papers in the field of SON, Cognitive Radio and Spectrum Sharing. She also has multiple pending patent applications involving SON technologies.

Dr. Mohamad Mehio, Nokia Mobile Networks CTO, Head of the Services Innovation

Mohamad Mehio [IEEE M'81, SM'09] (mohamad.mehio@nokia.com) is the Head of the Services Innovation of the Nokia Mobile Networks CTO in Naperville, Illinois. This team is responsible for innovation enabling the automation of network deployment and operations while ensuring that customers thrive and Nokia business grows. Previously, he was a senior director leading the Services Delivery Tools organization within the Alcatel-Lucent Wireless Business Group. Dr. Mehio began his career as a member of technical staff at AT&T Bell Labs in New Jersey and was initially involved in the design of forward looking systems in support of the automation of work centers. He holds B.Sc., M.Sc., and Ph.D. degrees all in Electrical Engineering from the University of Houston, Texas. He is also a graduate of the Columbia University Graduate Business School Senior Executive Training Program. He holds three patents.

Peter Gardell, Nokia Mobile Networks CTO Services Innovation

Peter Gardell is a member of the Nokia Mobile Networks CTO team driving Services Innovation for Wireless industry for Network Planning and Optimization services related organizations throughout the company. He has over 28 years of experience supporting design, implementation, deployment, optimization and performance monitoring of wireless networks. He holds a BS Physics from Worcester Polytechnic Institute, Massachusetts and a MS EE from University of Connecticut, Storrs. Pete is currently focused on integrating new innovations and concepts like Predictive Analytics, Machine Learning and other Data Science in the services solutions portfolio to increase revenue.

2.6 Statement on Nokia Financial Capability to Offer SAS and ESC

Nokia is a multinational communications and information technology company, headquartered in Espoo, Finland. Nokia is a public limited-liability company listed on the Nasdaq Helsinki, Euronext Paris and New York Stock Exchange. A truly global company, we are 160 nationalities working in more than 100 countries. Nokia's reported revenue for the 2016 year was EUR 23.61 Billion.

Nokia is a global leader in creating the technologies at the heart of our connected world. Powered by the research and innovation of Nokia Bell Labs, we serve communications service providers, governments, large enterprises and consumers, with the industry's most complete, end-to-end portfolio of products, services and licensing. We are driving the transition to smart, virtual networks and seamless connectivity by creating one, single network for all services, converging mobile and fixed broadband, IP routing and optical networks, with the software and services to manage them seamlessly.

With an R&D spend of EUR 4.7 billion, our 40,000 research scientists and engineers continue to invent and accelerate new technologies that will increasingly transform the way people and things communicate and connect: 5G, ultra-broadband access, IP and software define networking, Cloud applications, IoT and security platforms, data analytics, as well as sensors and imaging.

Nokia has the needed financial resources to operate a SAS and ESC service for a minimum of five years. Nokia has not finalized how it will price its SAS and ESC service offerings and has considered multiple pricing schemes as outlined in Section 2.2.13.

3 Design of Nokia SAS and Nokia ESC

Figure 2 illustrates the Nokia Cloud based implementation of SAS and ESC functions.

3.1 Design of Nokia SAS

Figure 3 illustrates the functional architecture of the Nokia SAS. In the following, we discuss in detail its key component blocks.

Presentation, Operations and Configuration Engine (POC) Engine:

[redacted]

[redacted]

SAS Core

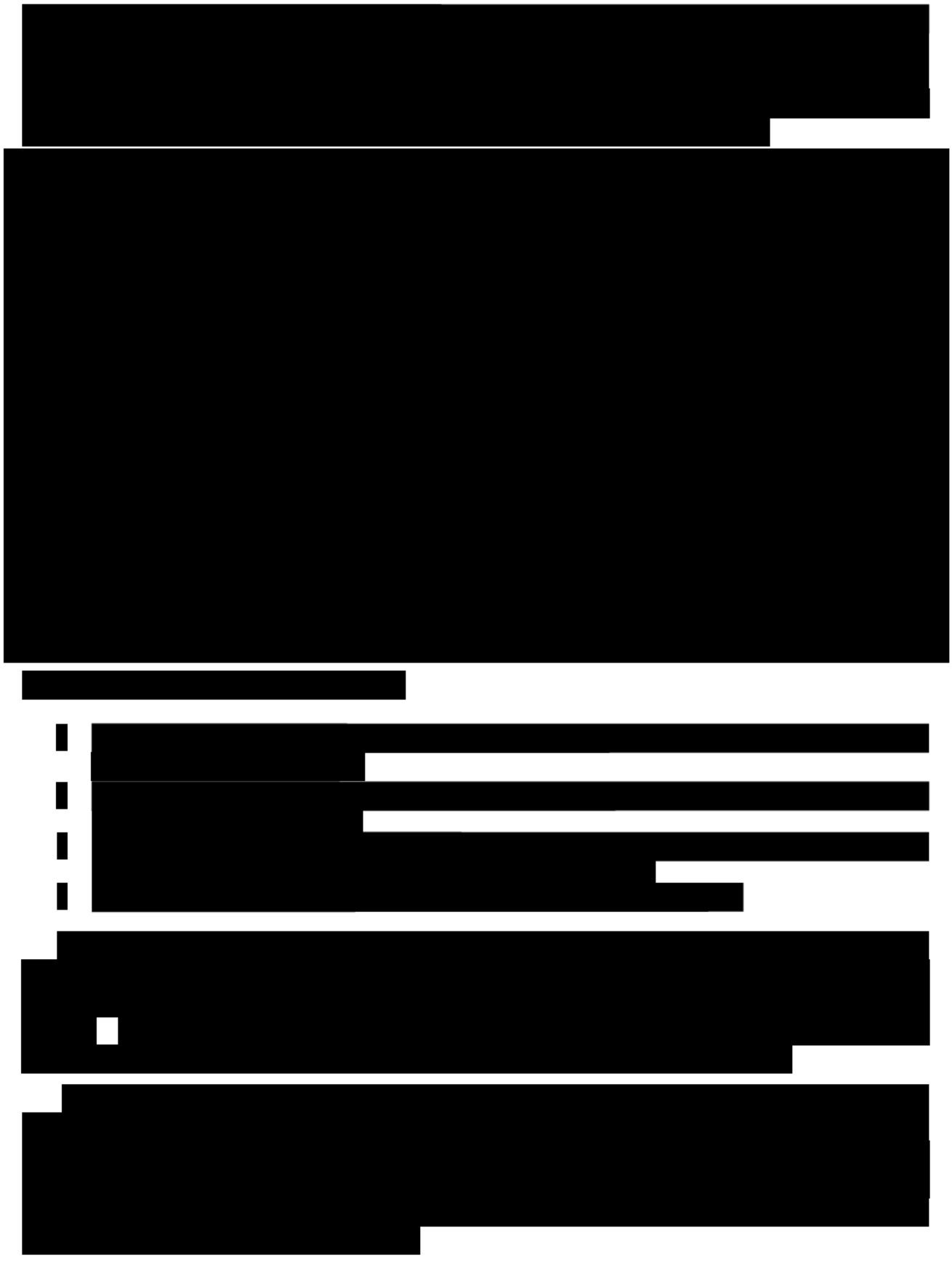
The SAS core implements two primary functions to support tiered access:

[redacted]

[redacted]

3.2 Design of Nokia ESC

Nokia is a leader in the industry in the development and production of RAN equipment. The Nokia RF Scanning business unit is dedicated to RF probe solutions. Nokia will leverage its capabilities and its experience building such probe solutions to build a responsive ESC cloud service that is responsive to incumbent events and that can ensure that incumbent protection guarantees are met. The Nokia ESC solution, illustrated in Figure 6, will consist of two parts: (1) the Nokia ESC Sensor and (2) the Nokia ESC Cloud.



[redacted]

3.2.1 *SAS and ESC integration*

Accurate detection of radar signals requires that the signal energy received in the sensor antennas from PAL and GAA CBSDs operating near ESC sensors sites is minimized to a low threshold. It is anticipated that this condition will be realized by implementing small restriction zones around ESC sites wherein no CBSDs are granted channels. The ESC sensors will register their antenna site location and required restriction zone to their corresponding SAS. Nokia SAS will enforce such restriction zones and also propagate information about them to other SASs via SAS-SAS interface.

The Nokia ESC Cloud will inform the Nokia SAS of the specific spatial areas and channels that need protection based on following conditions:

(1) [redacted]

(2) [redacted]

(3) [redacted]

[redacted]

3.3 Propagation Models in Nokia SAS

[redacted]

3.4 Affirmation of Compliance with Rules for SAS and ESC Operation

Nokia, Inc. affirms that it will comply with all applicable rules regarding SAS and ESC operation, as well as applicable enforcement mechanisms and procedures.

4 Details on SAS Operation

In the following, we discuss in detail various aspects of SAS operation and its interfaces.

4.1 SAS Communication methods

Nokia SAS communicates with (1) CBSDs, (2) other SASs in the ecosystem, (3) FCC databases (for acquiring information on (a) co-channel, adjacent channel and in-band incumbent FSS systems, (b) FCC ID data for certified CBSDs from various manufacturers, and (c) data on auctioned PALs), (4) databases that provide geospatial data such as census tract data, and (5) Nokia ESC and other ESCs in the ecosystems.

4.1.1 *SAS-CBSD Communication and interfaces*

Nokia SAS supports WInnForum standardized SAS-CBSD protocol (V1.0, Nov 2016) and will continue to upgrade its support as new features and capabilities are standardized in this protocol.

This protocol consists of a series of Request-Response exchanges via POST method of web protocol exchanged over secure HTTPS connection, wherein the CBSD initiates the request and SAS issues a response.

The protocol supports four key capabilities:

- Communicate device registration information (such as device ID, vendor ID, owner ID, location, antenna height, antenna characteristics, *etc.*) obtained from the device or via a professional installer. A secure registration record is created within the SAS after successful completion of this message exchange.
- Message exchange in the form of a Spectrum Inquiry Request-Response for a CBSD to enquire spectrum channels available at the CBSD location. If successfully completed, CBSD will receive a list of channels, from which it can select one or more channels to operate on.
- Message exchange in the form (GrantRequest-Response) for a CBSD to request a spectrum grant based on a list of available channels from the previous exchange. Successful completion of this exchange signifies that the SAS has permitted CBSD to use all or a subset of channels it requests grants for.
- Message exchange in the form (Heartbeat Request-Response) to authorize radio transmission on granted channels for a duration of the heartbeat interval.

The Heartbeat response message in this protocol allows SAS to stop transmissions on in-use CBRS channels in the event an incumbent arrival requires CBSD to vacate the channel.

4.1.2 *SAS-SAS Communication*

Nokia SAS will implement WInnForum standardized SAS-SAS protocol [6]. Using this simple request-response protocol, Nokia SAS will send and receive updates to and from peer SASs, employing PUSH via HTTPS POST and PULL via HTTPS GET methods. This protocol currently supports methods to push or pull information about various aspects of the SAS and CBRS ecosystem, specifically information on (1) SAS Administrators, (2) SAS Implementations, (3) CBSDs, (4) CBSD Type, (5) Incumbents, (6) various ESCs, and (7) Zone records. The information returned for a PULL or sent in for a PUSH is formatted using JSON objects and may contain individual records or all records in a time range. Nokia SAS will continue to support further extensions as they get standardized to add new information sharing capabilities such as support for newly assigned PALs and subleased PPAs.

4.2 SAS Data Security

Nokia has vast experience protecting the privacy of multiple customer datasets and has successfully addressed data management and operational security challenges in large-scale, widely-deployed advanced software solutions such as Customer Experience Management ("CEM"), SONs, Network Management Systems ("NMS"), and Subscriber Geolocation. Each of these solutions is part of the Nokia Applications & Analytics ("A&A") division and is required to adhere to Nokia Security process framework.

FCC rules and industry consensus in forums such as WInnForum and CBRS Alliance mandates CBSD information to be shared across the SAS-SAS interface. This information will be available beyond a SAS administration boundary and a subset of it could be publicly available.

As of the writing of this submission, there continues to be significant debate on what information about CBSDs must be minimally shared across SAS-SAS interface. For example, some prospective RAN operators have expressed resistance to sharing detailed location and performance data of CBSDs. Nokia intends to help build this consensus through its active participation in WInnForum and CBRS Alliance.

4.3 SAS Data Retention

Nokia SAS will fully comply with data retention requirements outlined in the Part 96.55 of the FCC's Rules. Specifically, it will (1) maintain a record of the location of protected earth stations as well as registration information required by 47 C.F.R. § 96.17; (2) maintain records not pertaining to federal Incumbent User transmissions for at least 60 months [4, 96.55]; and (3) only retain records of information or instructions received regarding federal Incumbent User transmissions from the ESC in accordance with information retention policies established as part of the ESC approval process. [4, 96.55].

Nokia SAS will not make CBSD registration information available to the public any earlier than seven days from when the information is collected to obfuscate incumbent activity and thus, maintain operational security of the incumbent.

Nokia will provide a documented and approved approach to obfuscate the incumbent frequency in its channel availability lists and channel reassignment mechanisms.

4.4 Interoperation with other SASs in the Ecosystem

Nokia SAS will interoperate with all available SASs that are known to operate in the USA and are reachable over the public internet over a secure connection using the WInnForum SAS-SAS protocol.

4.5 Handling Interference Complaints and Resolution Process

In the first phase of CBRS ecosystem evolution, we anticipate interference complaints to be raised by a CBSD device or network owner or user. Nokia SAS will support web-based tools to enable reporting of interference incidences and bring such reported events to the express attention of SAS administrators using internet tools such as automated email, text and emergency alert messages. It will provide analytic tools to zero-in on CBSD and incumbent activity and channel assignments in the spatial proximity of the reported incidence location over the period of interference. It will provide a summary analysis of the likely cause of reported interference.

At present, Nokia SAS intends to support enforcement actions that may involve a "human-in-loop" to turn off offending CBSDs. Nokia Bell Labs is conducting innovative research into automated interference detection and enforcement tools and may be able to support these technologies in the future evolution of its SAS offering.

4.6 Physical Security of Nokia SAS

Nokia has vast experience in operating complete end-to-end carrier grade wireless networks. Nokia maintains and manages ultra-secure data centers (of its own or of the operators it serves) to host many services (such as authentication, billing, mobility management, analytics) that require "5 nines" reliability and security. In the following, we describe how security and reliability of Nokia SAS and ESC will be guaranteed by leveraging the Nokia EE Cloud environment.

[redacted]

Table 1: Nokia AirFrame data center sample configuration

[redacted]

4.7 Protection of FSS Earth Station and Legacy (Grandfathered 3650-3700 MHz) WISP Licensees

Nokia SAS will protect existing FSS Earth Stations in the 3600-3650 MHz Band, the 3650-3700 MHz Band, and the 3700-4200 MHz Band as required in 47 C.F.R. Part 96.

3600-3650 MHz Earth stations: Earth stations listed at http://fcc.gov/cbrs-protected-fss-sites will be protected from CBSD operation consistent with key requirements described below. The protections will only apply to registered FSS earth stations that are authorized to operate on a co-primary basis consistent with 47 CFR § 2.106.

3650-3700 MHZ FSS earth stations: Nokia SAS will protect these FSS earth stations much the same as 3600-3650 FSS after the conditions outlined in 47 CFR § 96.21 are satisfied.

Nokia SAS will use the following methodology:

Co-channel impact: Nokia SAS will perform propagation-based computations to estimate aggregate passband RF power spectral density at the location of an FSS earth station operating in the 3600 – 3700 MHz band, produced by emissions from all co-channel CBSDs (within 150 km) and ensure that it does not exceed a median RMS value of -129 dBm / MHz.

Blocking impact: Nokia SAS will compute estimates of aggregate RF power at the output of a reference RF filter and antenna at the location of an FSS earth station operating in the 3600 – 3700 MHz band, produced by transmissions from all CBSDs (within 40 km) and ensure that it does not exceed a median RMS value of -60 dBm.

3700-4200 MHz FSS Earth Stations: Nokia SAS will employ following methodology:

Out-of-Band Emissions (OOBE) into FSS receiver: Nokia SAS will use propagation modeling-based computations and CBRS data to estimate aggregate passband power spectra density at the antenna locations for 3700-4200 MHz Telemetry, Tracking and Control ("TT&C") Radars listed in FCC database at http://fcc.gov/cbrs-protected-fss-sites. Specifically, it will ensure that aggregate emissions of CBSDs within 40 km of these radar locations do not exceed median RMS value of -129 dBm/MHz.

Blocking: Nokia SAS will use similar calculations as above to ensure aggregate RF power from CBSDs within 40 km area of these TT&C radar locations does not exceed -60 dBm.

4.7.1 *Protection of Legacy WISP and Utility Operations*

As per the FCC's 3.5 GHz CBRS rules, existing WISP and utility operations that use the 3650-3700 MHz portion of the CBRS band will be granted Incumbent User status consistent with 47 C.F.R. Sections 90.1307 and 90.1338. The protection offered will be in the form of protection zones around designated legacy WISP deployments. Nokia SAS will enforce these protection zones around base/fixed stations registered in the FCC ULS database as of April 17, 2015 and constructed and compliant with 47 C.F.R. Par 90 subpart Z specification by April 17, 2016.

Use of higher power CPE CBSD to achieve longer range and better link budget is allowed in 3650-3700 MHz and protected under the FCC's guidelines for protection of Grandfathered WISP licensees. As per these guidelines, registered CPEs that can use higher power can be at 18 Km from the base station whereas unregistered CPEs with lesser power (1W/25 MHz) can be at distance of 4.4 km.

Given that the impact of uplink transmissions from higher power CPEs to low power EUDs in other serving CBSDs in the region can be substantial, the SAS needs to make every effort to allocate GAA CBSDs in the region with orthogonal CBRS channels. Specifically, it needs to acquire accurate information on WISP deployments and compute sectors of protection contours for registered and unregistered CPEs used in those sectors. If there are registered CBSDs in those contours, it will allocate different channels than the ones used by Grandfathered WISP licensees.

4.7.2 *SAS Mechanisms for Compensating CBSD Out-of-Band Emissions (OOBE) Performance Limits*

The Out-of-Band-Emissions ("OOBE") limits mandated in current 3.5GHz CBRS rules are quite stringent and can be satisfied for 5 and 10 MHz channel bandwidths. However, for wider channel width (*e.g.*, 20 MHz) which are quite attractive for achieving higher spectral efficiency and creating large wireless capacity, Nokia and industry-at-large have expressed concerns that transmit power may have to be reduced

as much as 3dB (*i.e.*, by a factor of 2) to maintain OOBE compliance. Despite industry requests, the FCC has not relaxed these OOBE limits. [redacted]

[redacted]

4.8 Protection of DOD and Navy Operations

Nokia SAS will enforce exclusions zones along US coastlines as outlined in http://ntia.doc.gov/category/3550-3650-mhz until an ESC is certified as specified in 47 C.F.R. Section 96.67. After ESC certification and availability of ESC service, Nokia SAS will convert Exclusion Zones to Protection Zones and offer service to Category A and B CBSDs consistent with available and in-use frequency information obtained from the ESC.

When an ESC reports an incumbent event impacting a protection zone, Nokia SAS will guarantee evacuation and possible channel reassignment for CBSDs in the impacted region in less than 300 seconds.

Nokia SAS will also support a coordination procedure (expected to be outlined by the FCC) to protect temporary federal naval radars – including visits to non-homeports – from interference. This support will ensure that federal incumbent users may receive protection when they (infrequently) visit locations not covered by the coastal Exclusion Zones.

Nokia SAS will enforce 80 km exclusion zones around federal radiolocation service sites listed in 47 C.F.R. Sections 90.1331 and 2.106 Footnote US109 until an ESC is approved to guarantee protection from CBSDs in 3650-3700 MHz. Once ESC service is approved and available, Nokia SAS will convert the exclusion zone to a protection zone and rely on an ESC to notify availability of frequencies in these areas before granting any channels to CBSDs. It will also ensure that if the ESC notifies appearance of the federal system signal, it will evacuate CBSDs from impacted/revoked frequencies and, if possible, reassign them.

To support strong operational security for incumbents, Nokia SAS will (1) obfuscate the information on when the detected incumbent activity ends and (2) also, implement authorization limiting techniques in its channel assignments to CBSDs.

4.9 Statement on Completeness of Nokia SAS Operations with 47 C.F.R. Part 96, Subpart F

Nokia SAS will implement and continually support all functional requirements detailed in 47 C.F.R. Part 96, subpart F. The operation of Nokia SAS depends only on information supplied by entities in the CBRS ecosystem – namely CBSDs, ESCs when available, and other operating SASs – as well as

information collected from mandatory sources such as FCC databases and data sources (such as census tract information databases).

5 Details on ESC operation

5.1.1 *SAS-ESC Communication Interface*

Nokia SAS to ESC communication uses standard HTTPS POST and GET messages to support information PUSH from ESC to SAS and SAS to ESC. The ESC disseminates just enough information about incumbent activity that is sufficient to protect the incumbent, such as description of spatial footprint of the exclusion zone, frequencies that need to be protected, time at which exclusion zone needs to be activated or deactivated and how the information should be handled (*e.g.*, amount of time information can be retained, analyzed and presented). Given the minimal nature of this information exchange, currently Nokia plans to use a proprietary protocol for the sake of expediency. However, in case WInnForum standardizes this exchange to enable multi-vendor operation, Nokia will consider supporting it.

5.1.2 *ESC Sensor to ESC Cloud Communication*

The communication between the Nokia ESC cloud and Nokia ESC Sensor is proprietary in nature and carried out on a secure SSL over TCP/IP interface. When the sensor boots, it performs a simple registration with the ESC cloud, wherein it includes details on its model number, software version and details on the sensor capabilities. On successful registration, it provides periodic heartbeats to ensure that the ESC cloud is reachable and to indicate to the ESC that it is "operational." The ESC Cloud provides sensor configuration and operational parameters, such as threshold for incumbent activity detection, frequency of slow and rapid scanning and reporting of summary reports.

In the event observed data exceeds the incumbent activity threshold, the ESC sensor immediately forwards the event to the ESC Cloud and includes information such as the frequency over which a threshold violation is observed and the time stamp of measurement that detected the event. The decision logic in the ESC cloud further processes this event and subsequent updates to infer arrival and departure of an incumbent.

5.2 Security of ESC Data

Nokia's ESC solution shall be compliant with the security considerations described in FCC 15-47 (R&O and Second FNPRM) Paragraph 330 [2]. Specifically:

- The ESC communicates with the SAS via secure transport channels to prohibit unauthorized access to incumbent sensing information.
- The ESC does not have any physical or logical interface to US Military or secure Federal systems and does not require input from such systems.
- The Nokia ESC sensors and ESC cloud do not disclose movement or present location of US military assets nor does it attempt to identify such movements. Its intelligence and functionality are limited to detecting energy levels and features of the spectrograms in measurement

bandwidths relevant to the CBRS program regardless of the origin of such energy. At the time of certification, Nokia will identify intermediate variables if any, that, if combined, could be used to form a position estimate.

- The ESC, Domain Proxy and SAS equipment referenced in this proposal will be compliant with the FCC's FNPRM, FCC 15-47, Paragraph 330 regarding long term storage and or correlation of detected interference patterns such that current or historical movement of US Military assets cannot be determined based on this sensed interference data.
- At the time of ESC certification, Nokia will provide details on management of and allow review of cyber security risks in its ESC design supply chain.
- Nokia ESC sensors will employ tamper proof hardware and a Trusted Privacy Module ("TPM") to generate dynamic security credentials (*e.g.*, encryption keys) that will be used for secure communication with the ESC Cloud. Nokia ESC design will also include mechanisms for continuous checks on integrity of the sensor hardware and software systems. At the time of certification, Nokia will provide details on measures and mechanisms it will employ to (1) limit reconfigurability, (2) maintain secure remote access, and (3) detect and prevent tampering of its ESC sensor.
- The Nokia ESC solution will be modified as necessary to remain current as these security provisions evolve per the FCC's FNPRM, FCC 15-47, Paragraph 330.

5.3 Statement on Completeness of ESC

Nokia ESC will implement and continually support all functional requirements detailed in 47 C.F.R. Part 96, subpart F. The operation of Nokia ESC aimed at detecting activity of incumbents does not depend on information or inputs supplied by Government or any other sources.

Respectfully submitted,

Nokia

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